Fermi National Accelerator Laboratory

FERMILAB-Conf-94/186-E

E791

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July 1994

Accepted by *ICHEP94*, July 20-27, 1994

Operated by Universities Research Association Inc. under Contract No. DE-AC02-76CHO3000 with the United States Department of Energy

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ICHEP94 Ref. 0490
Submitted to Pa 02

PU-HEP-94-13
FERMILAB-Conf-94/186
10th May 1994

$D^0 - \overline{D}^0$ mixing and Doubly Cabibbo-suppressed Decays of the D^+

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Abstract

This report summarizes results from Fermilab experiment E791 on D^0-$\overline{D}^0$ mixing and doubly Cabibbo-suppressed decays of the D^+ meson.

D^0-$\overline{D}^0$ mixing is expected to be very small in the standard model, with mixing rates predicted in the range 10^{-10} to 10^{-7}. This provides us with a large window to study effects beyond the standard model. For instance, recently Lawrence Hall and Steven Weinberg [Hall 93] have explored the consequences of an extension of the standard model involving charged Higgs bosons. They predict an extremely small amount of direct CP violation in neutral kaon decays and also very small CP violating effects in decays of B mesons. However, one testable prediction is a large amount ($\sim 0.2\%$) of $D^0 - \overline{D}^0$ mixing . Other models [Babu 88, Ma 88] also predict large (relative to the standard model) $D^0 - \overline{D}^0$ mixing . These include supersymmetric models, models involving a fourth generation and models with left-right symmetry.

The E791 detector allows us to separate a mixing signal, if any, from the doubly Cabibbo-suppressed decay which has the same final state particles by utilizing the different time dependence of the signal. Therefore we have begun a determination of the amount of $D^0 - \overline{D}^0$ mixing , if any, using 1/3 of the E791 data sample. The detailed analysis is written up as an E791 internal memo [Purohit 94]. The highlights are presented below.

In order to search for $D^0 - \overline{D}^0$ mixing , we use only D^0 mesons from D^{*+} decays in which case the charge of the pion from the D^{*+} decay identifies the charm quantum number of the D^0 at birth. When the D^0 decays, the charge of the kaon identifies the charm quantum number and this way we can tell if mixing has occured. This kind of search can be carried out by CLEO II as well and their conclusion was that there is some evidence of a wrong sign signal ($0.77\pm0.25\pm0.25$)% of the right sign signal. However, because of a lack of lifetime information, they cannot distinguish between doubly Cabibbo-suppressed decays which are expected at the level of the observed signal and mixing. We use our excellent lifetime sensitivity to obtain separate limits.

The right-sign ($D^0 \to K^-\pi^+$) and wrong-sign ($D^0 \to K^+\pi^-$) signals from 1/3 of E791's data are shown in Figure 1. In these plots the q-value is a mass difference defined by

$$q = m_{K\pi\pi} - m_{K\pi} - m_\pi$$

. The lifetime distribution of the wrong-sign sample after background subtraction and correction for acceptance is shown in Figure 2.

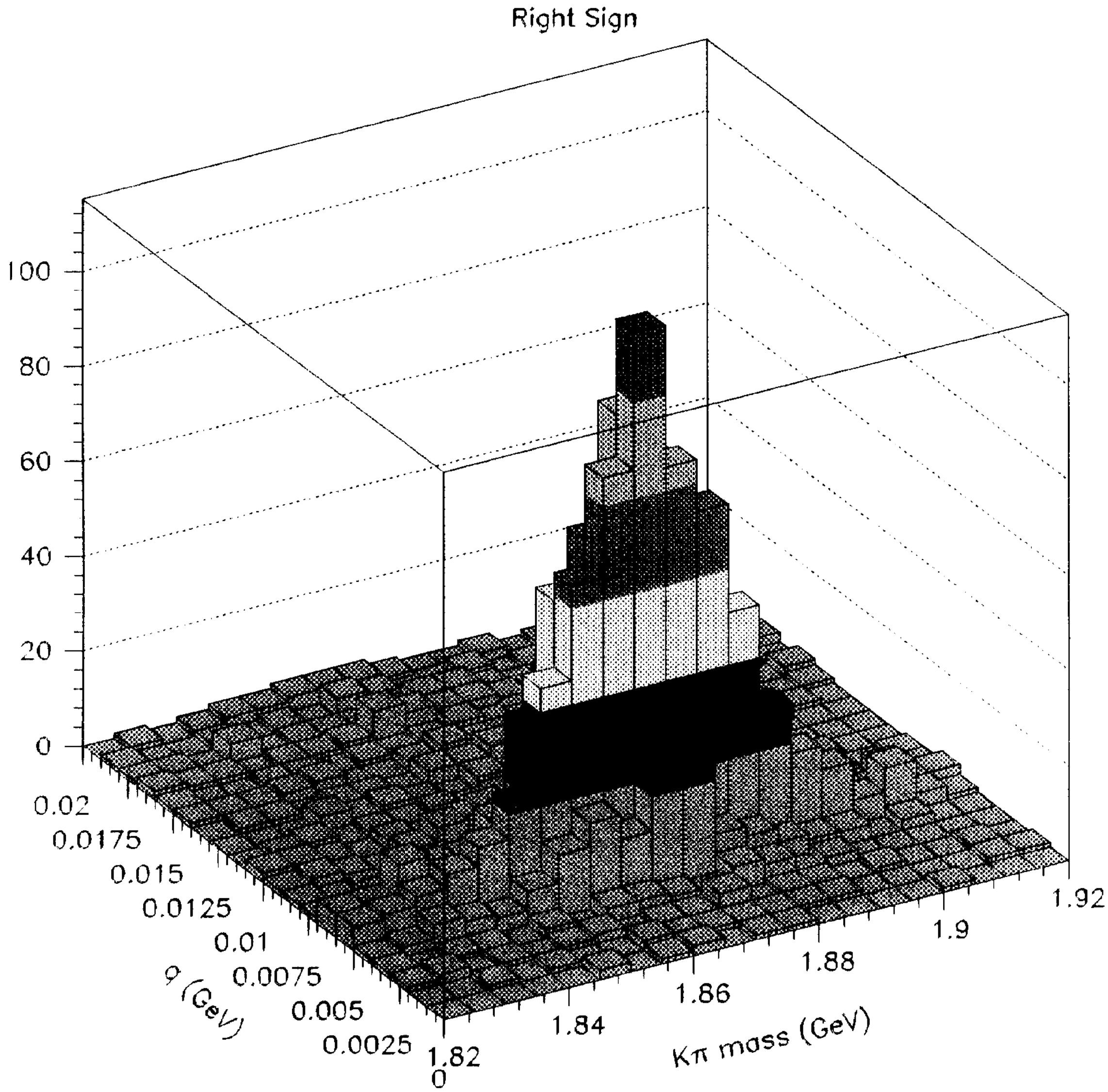

Figure 1a. The right-sign ($D^0 \to K^-\pi^+$) decay candidates. The number of events are plotted versus $m_{K\pi}$ and q in the D^{*+} decays.

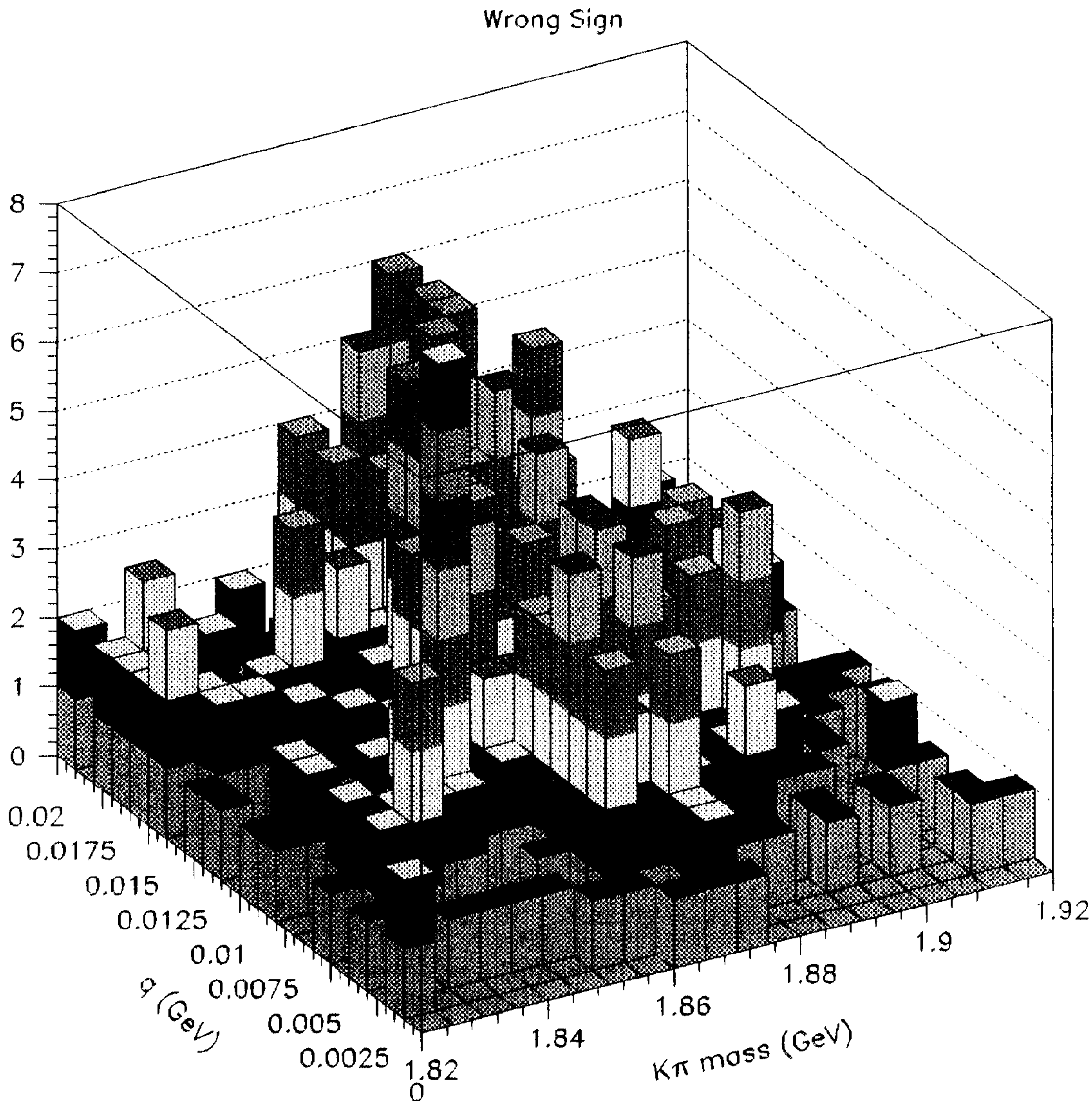

Figure 1b. The wrong-sign ($D^0 \rightarrow K^+\pi^-$) decay candidates. The number of events are plotted versus $m_{K\pi}$ and q in the D^{*+} decays.

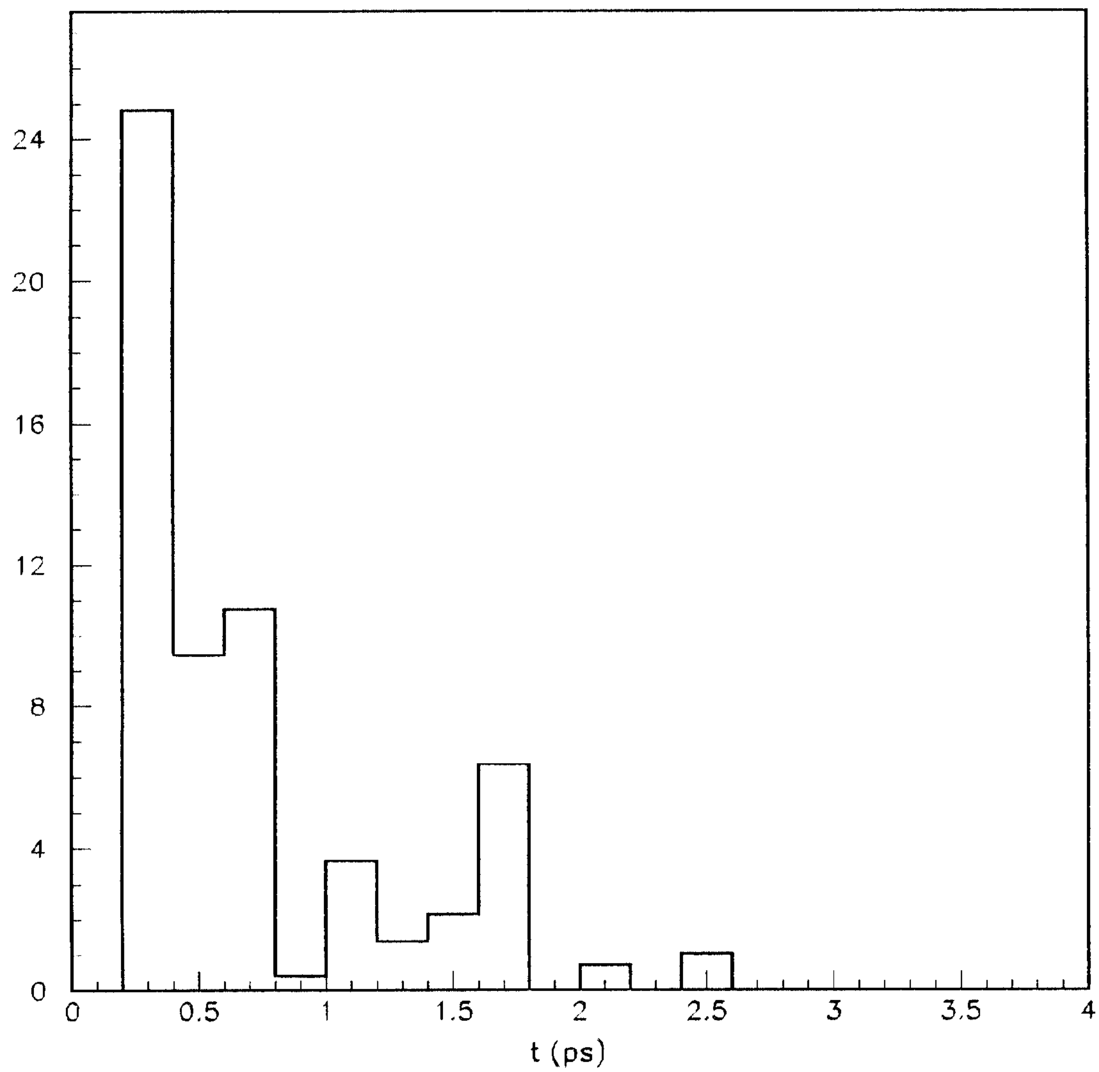

Figure 2. The time distribution of wrong sign $D^0 \to K^-\pi^+$ decays in the signal region. The distribution is background subtracted and acceptance corrected.

We perform an unbinned maximum likelihood fit to $m_{K\pi}$, q in the D^{*+} decay and the lifetime of the D^0 in right- and wrong-sign samples to obtain the the rates (r) of mixing or doubly Cabibbo-suppressed decays. The rate r e.g., for mixing is defined by

$$r_{\text{mix}} \equiv \frac{\Gamma(D^0 \to \overline{D}^0 \to K^+\pi^-)}{\Gamma(D^0 \to K^-\pi^+)}$$

The results are:

$$r_{\text{mix}} < 0.47\%@90\%\text{CL}$$

and

$$r_{\text{DCSD}} < 2.7\%@90\%\text{CL}$$

or

$$r_{\text{DCSD}} = 1.9^{+0.6}_{-0.8}\%$$

Already, these limits are the world's best limits on mixing. For comparison, E691 obtained a limit [E691 88] of $r_{\text{mix}} < 0.50\%$ in the $K\pi$ mode and $r_{\text{mix}} < 0.37\%$ combining the $K\pi$ and $K\pi\pi\pi$ decay modes of the D^0. If we repeat our analysis using parabolic errors the way E691 did, our limit is 0.37%, better than E691's limit of 0.50%. Since our limit comes from 1/3 of our data set and from only one of the two important D^0 hadronic decay modes, we expect that with the full data set, both modes and further analysis improvements, the sensitivity will improve by around a factor of 3. Already, a preliminary analysis in the $D^0 \to K\pi\pi\pi$ mode indicates that

$$r_{\text{mix}} < 3.0\% \qquad \text{(Assuming maximal interference from DCSD)}$$

and that

$$r_{\text{mix}} < 0.3\% \qquad \text{(Assuming no interference from DCSD)}$$

E691 also obtained $r_{\text{DCSD}} < 1.5\%$. Our limit appears a little worse simply because we may have begun to see the signal that CLEO II sees.

During the past year, we have been working on extracting D$^+$ doubly Cabibbo-suppressed decay signals from E791's data sample. These decays are interesting both because they have never been observed and because definite predictions have been made about their rates, based on models of D mesons and their decay mechanisms. Preliminary analyses of 1/3 of our data have now been completed. Figure 3 shows our Cabibbo-favored signal $D^+ \to K^-\pi^+\pi^+$ and the the next figure shows the signal in the doubly Cabibbo-suppressed mode $D^+ \to K^+\pi^-\pi^-$. There is a clear signal

$$\frac{\Gamma(D^+ \to K^+\pi^-\pi^+)}{\Gamma(D^+ \to K^-\pi^+\pi^+)} = (3.9 \pm 0.9 \pm 0.5) \times \tan^4\theta_c$$

This is already a much better limit/signal than the Particle Data booklet [PDG 92] limit of $20 \times \tan^4 \theta_c$. When we examine the resonant subcomponents we find that

$$\frac{\Gamma(D^+ \to K^{*0}\pi^+)}{\Gamma(D^+ \to K^-\pi^+\pi^+)} < 2.9 \times \tan^4 \theta_c$$

If considered as a signal, we find that

$$\frac{\Gamma(D^+ \to K^{*0}\pi^+)}{\Gamma(D^+ \to K^-\pi^+\pi^+)} = (1.9 \pm 0.6) \times \tan^4 \theta_c$$

(statistical error only).

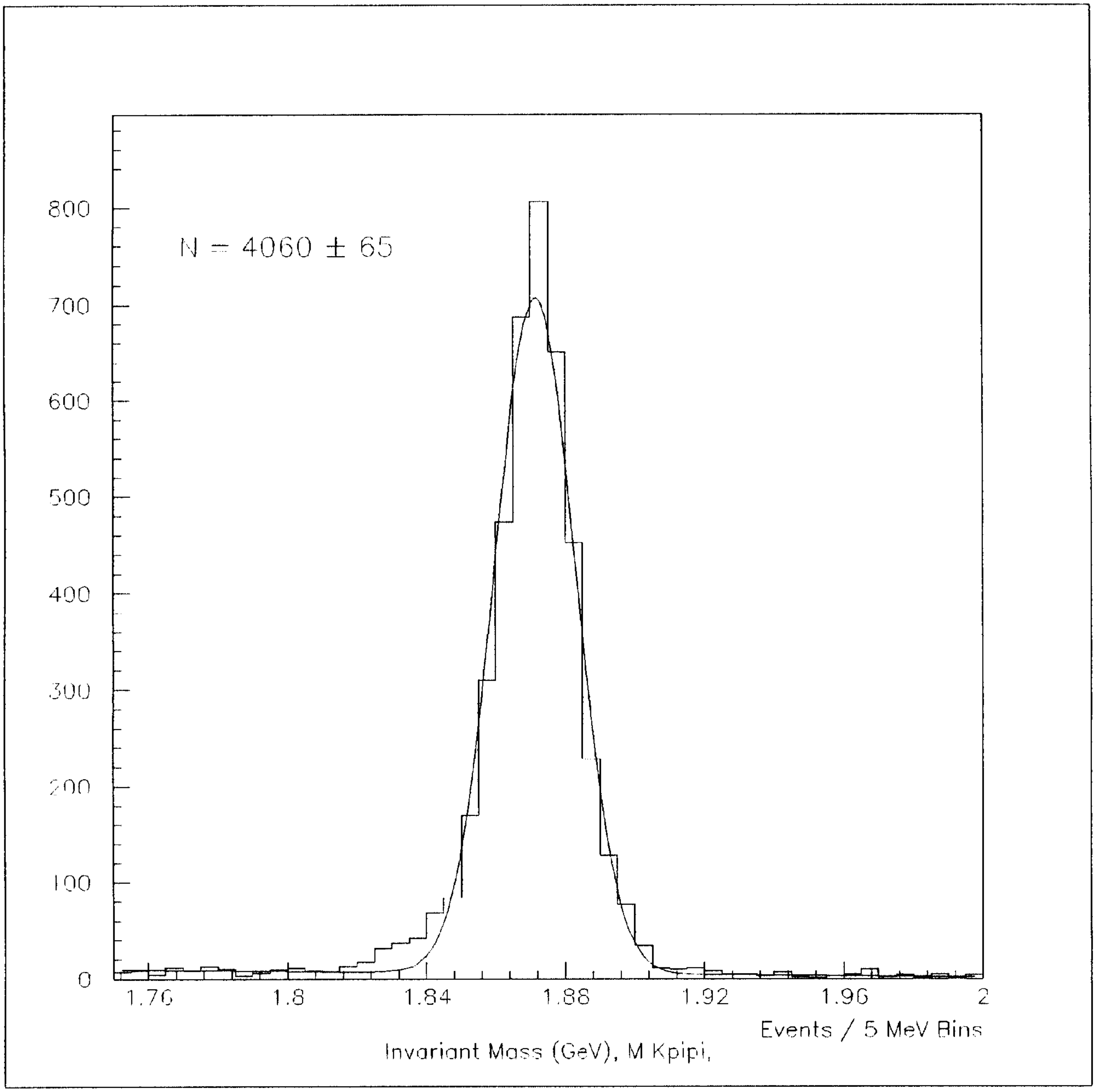

Figure 3. Invariant mass distribution for the Cabibbo-favored decay $D^+ \to K^-\pi^+\pi^+$ from 1/3 of the E791 data sample. This is used as normalization for the doubly Cabibbo-suppressed signal.

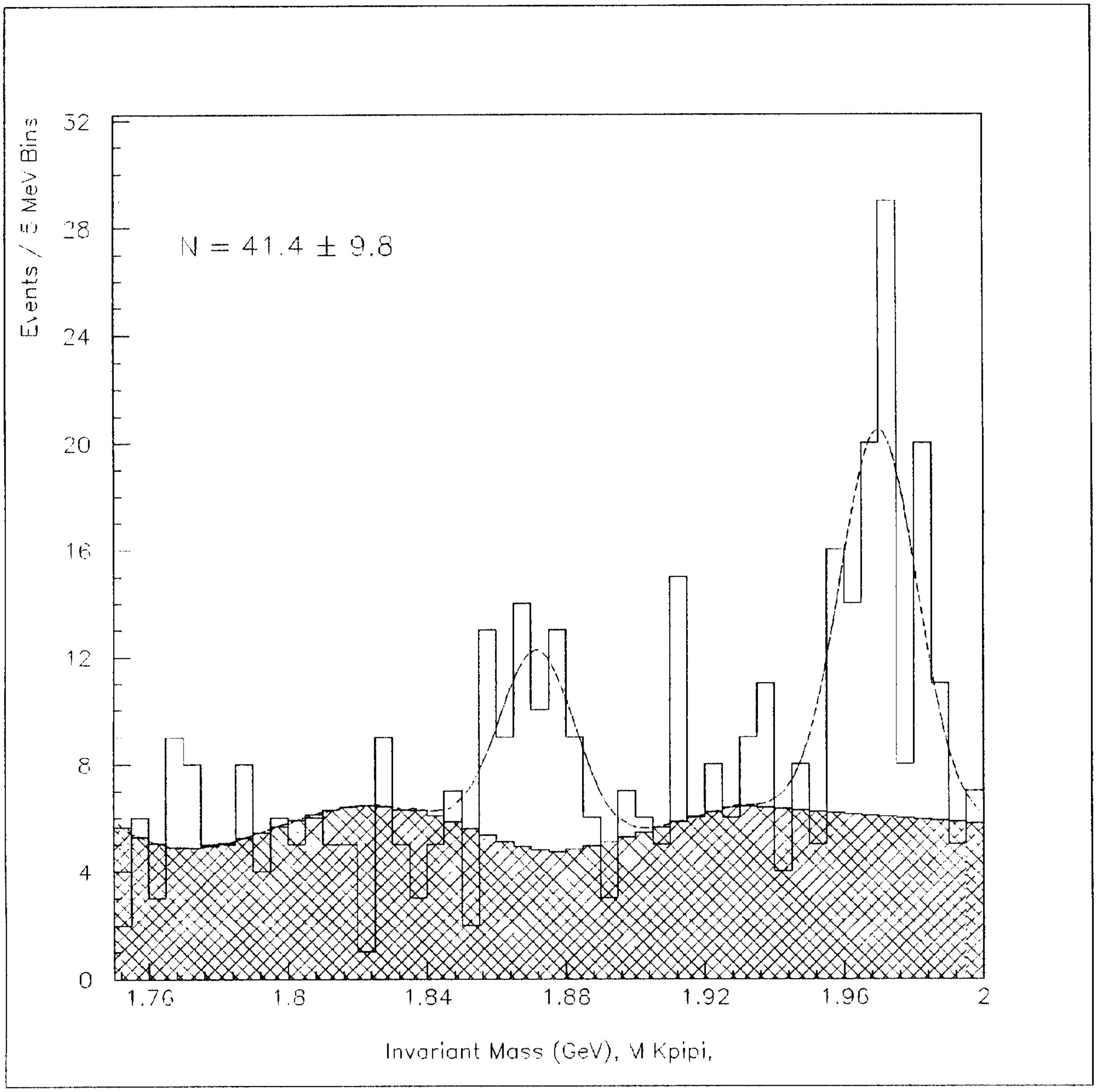

Figure 4. Invariant mass distribution for the doubly Cabibbo-suppressed decay $D^+ \rightarrow K^+\pi^+\pi^-$ from 1/3 of the E791 data sample.

Similarly, an examination of decays to three charged kaons has revealed that

$$\frac{\Gamma(D^+ \rightarrow K^+K^-K^+)}{\Gamma(D^+ \rightarrow K^-\pi^+\pi^+)} < 1.7 \times \tan^4\theta_c$$

and the resonant decay can be compared to the $\phi\pi^+$ decay mode giving

$$\frac{\Gamma(D^+ \rightarrow \phi K^+)}{\Gamma(D^+ \rightarrow \phi\pi^+)} < 20.3 \times \tan^4\theta_c$$

These limits are lower than the level at which WA82 has claimed a signal and a little lower than a signal observed by E691.

Our future plans are to continue analyses on mixing, doubly Cabibbo-suppressed decays, charm baryons, flavor-changing neutral currents, semileptonic decays etc.

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